

Appendix I

Filling and Emptying Systems for Extension of 600-ft Locks

I-1. Description

Lock extensions have been considered as a method to increase the capacity for existing navigation projects, especially those projects with a large main lock chamber and a smaller auxiliary chamber. Extension of an existing chamber presents many challenges, a primary one being minimum project closure to navigation. Research has been performed to investigate designs for lock extensions. This research focused mainly on extending an existing 670-ft lock chamber to accommodate a tow consisting of 15 barges (3 wide by 5 deep) and towboat. Each individual barge was 35 ft wide by 195 ft long.

Generally, filling and emptying systems for lock extensions can vary from simple to quite complex. Alternatives for lock extension are to extend the lock walls with no provisions for additional filling and emptying capacity, extend the lock walls and partially supplement the filling and emptying capacity, or extend the locks and provide an entirely new filling and emptying system for the extended section of the chamber. Economic and navigation safety issues are evaluated to determine the appropriate alternative. Extending the lock walls with no provisions for additional filling and emptying capacity is the least expensive alternative (initial cost). This alternative is also the most hydraulically inefficient (slow) and has the most risk from a navigation safety issue. A totally new filling and emptying system is the most hydraulically efficient (fast), but also has a higher initial cost.

I-2. Lock Wall Extensions with no Additional Filling and Emptying System

Lock chamber performance with lock wall extensions has been evaluated using physical models. Permissible filling times for the bottom lateral systems for both the J. T. Myers and Greenup auxiliary locks and the side port system for the existing Lock No. 25 Mississippi River have been determined from model studies. Figure I-1 presents these filling times. All of these locks are 110 ft wide, and the lengths from pintle to pintle are 1,320, 1,340, and 1,280 ft for J. T. Myers, Greenup, and Lock No. 25, respectively. The existing auxiliary lock for the J. T. Myers lock has a 16-ft-high by 14-ft-wide culvert with six laterals for filling and emptying. The Greenup lock has an 18-ft-high by 16-ft-wide culvert with eleven laterals. Lock No. 25 has 20 ports located in each of the two culverts. The culverts transition from rectangular (12.5 ft by 12.5 ft) to circular and back to rectangular with most of the ports in the circular section.

As seen in Figure I-1, the permissible filling times for J. T. Myers (item 106) and Greenup are significantly longer when only the existing filling and emptying system is used. The permissible filling times for 1,270-ft-long by 110-ft-wide side-port locks as presented in Appendix D, Figure D-5, are included in Figure I-1 for comparison. The permissible filling times for the extended locks are more than twice the permissible filling time for the conventional 1,270-ft-long side-port lock. In addition to much slower filling times, the chances for an accident are greater with this filling system since it is unbalanced. The extended lock is essentially an end filling system, and the water surface in the upper end of the chamber remains higher than the lower water surface for extended periods during filling. Accidental rapid valve operations or faulty mooring lines can result in the tow moving downstream quicker than expected. The following was taken from the *Waterways Journal* dated 27 November 2000:

“Upbound tows at the lock have reported experiencing a severe surge when the pit is being raised. Several tows have reported breaking wires on tow and lock lines while locking, and one tow hit the upper gate November 21.”

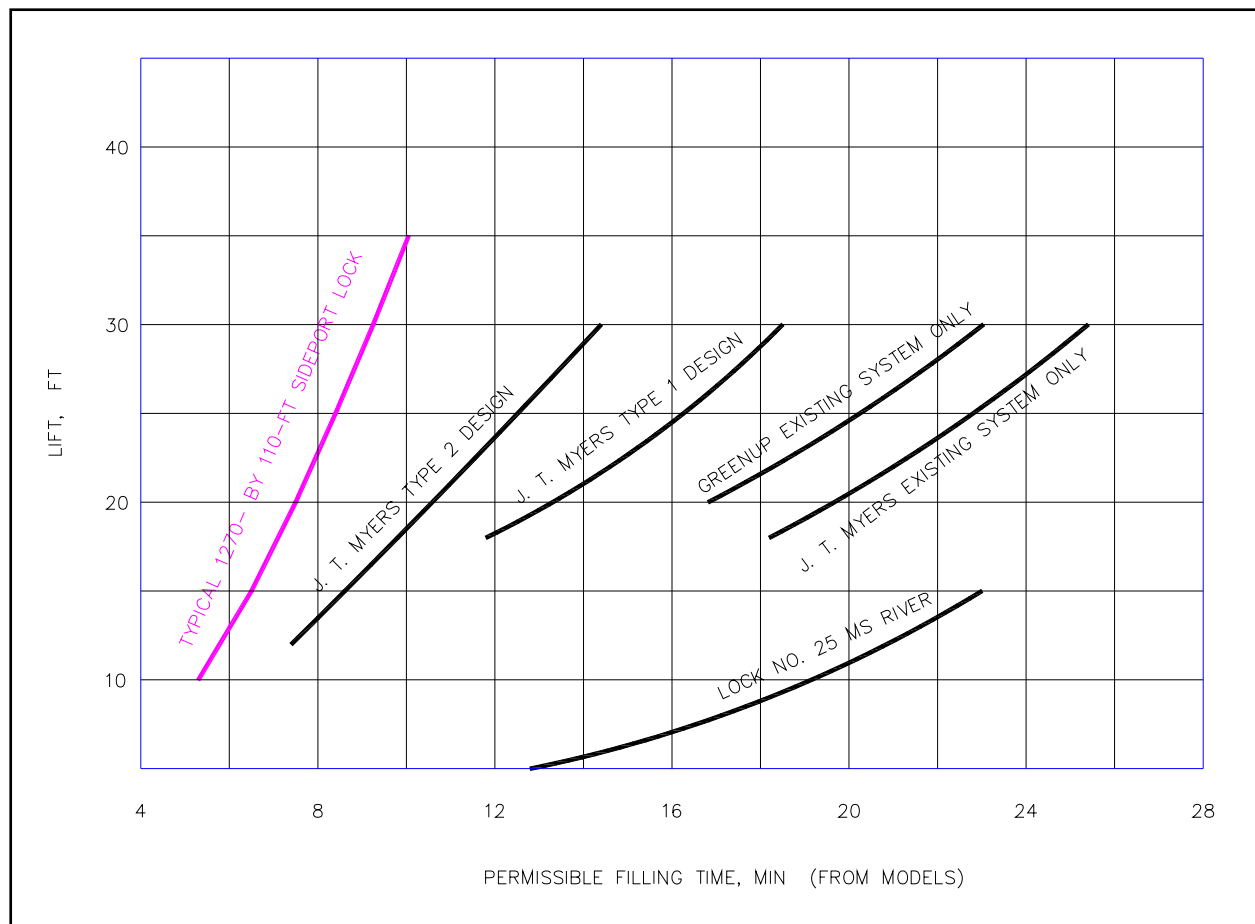


Figure I-1. Permissible filling times determined from lock extension models

These conditions in the chamber resulted from filling operations with one valve. The other filling valve was out of service for repairs. This system is a split lateral type with one culvert feeding a set of laterals in the upper half of the chamber and the other culvert feeding a set of identical laterals in the lower half of the chamber. The surging in the chamber reported above is caused from filling the chamber at one end, which is the case when one valve is out of service. Very long valve operations are required to avoid excessive hawser forces.

I-3. Lock Wall Extensions with Partial Supplemental Filling and Emptying

Modifying the existing filling and emptying to supplement the lock operations with the extended lock walls has been considered as an alternative for lock extension projects. Research performed using a model of an auxiliary lock similar to the Greenup project was conducted to determine chamber performance. The existing 18-ft-high by 16-ft-wide culvert was extended to the lower end of the chamber, and a lateral system similar to the upper laterals was installed in the lower end of the chamber. There was essentially no difference between the permissible filling times with this design and those with no supplemental filling. The flow entering the chamber was more balanced although long valve operations were still required to avoid excessive hawser forces. These results indicated that modification of the existing filling system in this manner was not beneficial. The existing culvert would need to be enlarged significantly to reduce filling times.

An alternative evaluated for Lock No. 25 during general research for the Upper Mississippi River locks was the addition of extra empty valves (item 101). Model experiments were performed with combinations of up to ten additional 10-ft-wide by 4-ft-high vertical slide valves (wagon wheel valves) located as shown in Figure I-2. The type 3 design evaluated during this research consisted of using empty valves 2, 4, 6, and 8 and the existing tainter valve provided desirable performance and actually was faster than using all ten extra valves. With all ten valves in operation, the valve speed had to be slowed to avoid high hawser forces. A comparison of the permissible empty valve times using only the existing tainter valve and the type 3 design empty valves is shown in Figure I-3. The type 3 design is more than twice as fast as using only the existing tainter valve to empty the chamber.

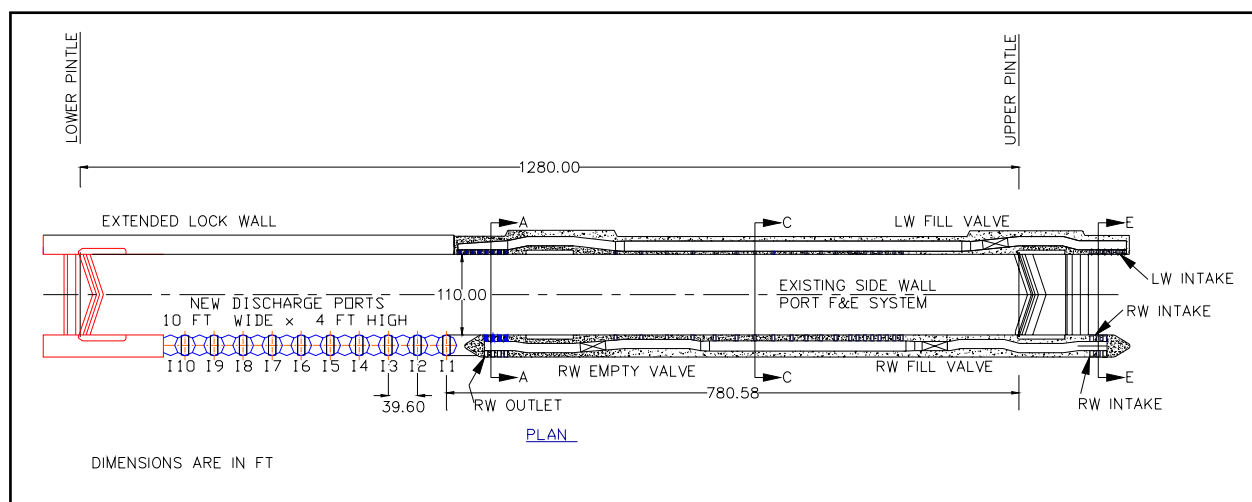


Figure I-2. Example of lock extension proposed for Upper Mississippi River projects

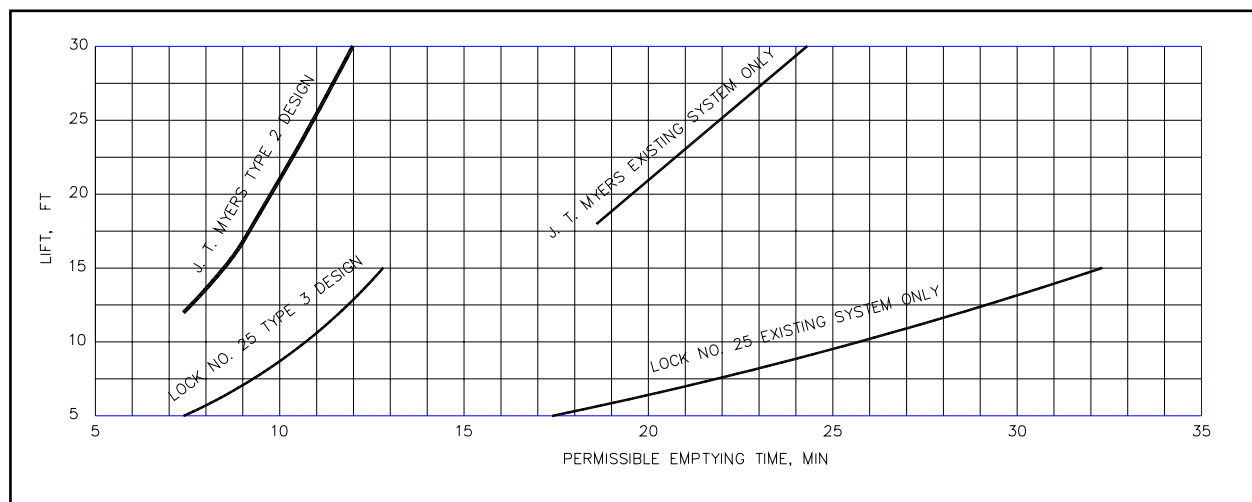


Figure I-3. Permissible emptying times determined from lock extension models

I-4. Lock Wall Extensions with Full Supplemental Filling and Emptying

The most hydraulically effective alternative for a lock extension is to provide an additional filling and emptying system for the extended lock chamber. Ideally, if the lock extension has the same dimensions of the existing lock (similar volumes), a system could be added that would provide the same filling and

emptying times as the existing auxiliary chamber. The extended lock section may not contain the same volume since float-in or in-the-wet construction techniques may require different size monoliths compared to conventional construction techniques. The new filling and emptying system could be designed to accommodate the change in lock volume and still provide a balanced system.

A low-cost supplemental filling and emptying system was developed for the J. T. Myers lock extension (items 105 and 106). The existing auxiliary lock filling and emptying system consisted of one conventional intake located in the landside guide wall and a new intake located in the upper miter sill of the auxiliary lock. The existing intake supplies a single 14-ft-wide by 16-ft-high landside culvert that connects to a bottom lateral (six laterals) system in the upper half of the lock chamber. The initial (Type 1 design) through-the-sill intake consisted of two triple box culverts with the inside dimensions of each barrel of the culvert 4.5 ft high by 8.0 ft wide. These culverts ran through the sill and transitioned vertically and laterally to the top of the lock floor where they were located adjacent to the lock walls (Figures I-4 and I-5). The outer dimensions of each culvert were 8.5 ft high by 30 ft wide. Both these culverts ran over the existing lateral field and near the midpoint of the chamber after passing over the existing emptying culvert, turn through the landside lock wall. The two culverts then transitioned to a single 14-ft-wide by 16-ft-high landside culvert. This single filling culvert supplied a bottom lateral system identical to that in the upper half of the chamber. During emptying, the existing laterals in the upper half of the chamber discharged back into the landside culvert, which turned and ran underneath the existing locks and discharged at an outlet bucket located outside the river wall of the main lock. The laterals in the lower half of the chamber discharged back into the landside culvert that connects to a landside outlet diffuser. The landside outlet diffuser was selected for the lock extension to minimize traffic delays during construction.



Figure I-4. View of through-the-sill intake for J. T. Myers lock extension

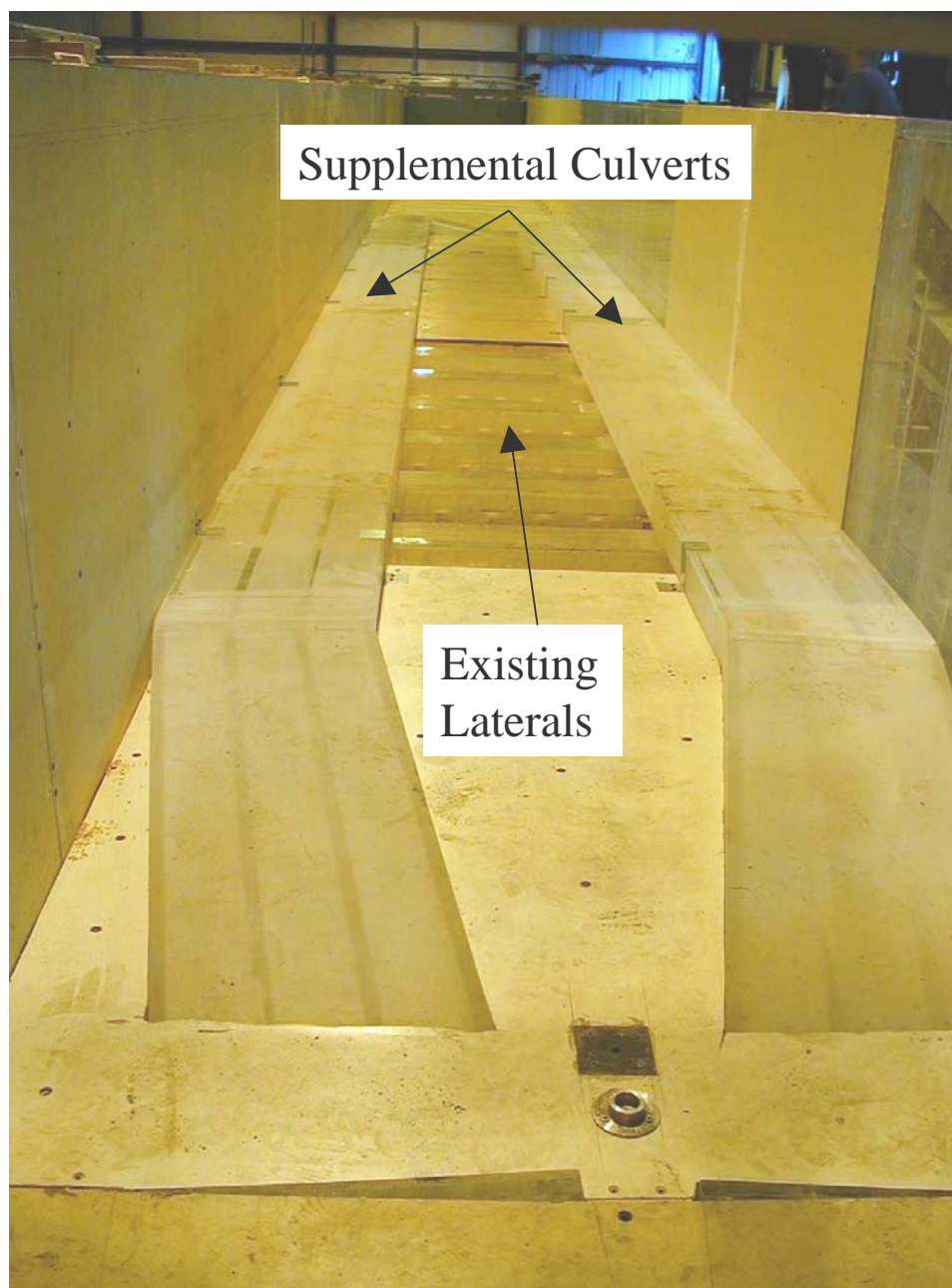


Figure I-5. J. T. Myers supplemental culverts

The permissible filling time determined with the type 1 design J. T. Myers supplemental filling and emptying system is shown in Figure I-1. A significant improvement in the permissible filling time was achieved with the supplemental system compared to using only the existing system to fill the lock. Increasing the size of the culverts and lowering the roof of the culvert (type 2 design) improved the supplemental system. Experiments indicated that if the tailwater was slightly lower than minimum (0.5 ft) and the tow in the chamber was drafted slightly more than 9 ft (say 0.5 ft), the tow could come into contact with the supplemental culvert during the underempty (overtravel) portion of the emptying operation. Lowering the roof of the culvert by 1 ft greatly reduced the chances of contact with the culvert. The permissible filling times determined for the J. T. Myers type 2 design filling and emptying

system are shown in Figure I-1. The type 2 design was 2 min faster than the type 1 design at the design lift of 18 ft. The permissible emptying times are shown in Figure I-3.

The most effective supplemental filling and emptying system for a lock extension project would be one that provided chamber performance identical to the chamber performance of the existing auxiliary lock. An undersized or oversized supplemental system would cause unbalanced flows into the chamber during filling and could result in high hawser forces. The Greenup Lock Extension project has proposed a supplemental system with a new intake and culvert that feed a set of laterals in the lock extension that are identical to laterals in the upper end. Physical model experiments indicated for the design lift of 30 ft, the permissible filling time is 12 min with the proposed supplemental system and 24 min using only the existing system to fill the extended chamber.

I-5. Valve Operations

Lock extension projects with no additional filling and emptying will require long valve times to avoid high hawser forces. The valves will control flow into and out of the chamber rather than the filling and emptying system. If partial or full supplemental filling and emptying systems are used, faster valve speed can be used depending on the system. Economic and risk analyses will determine the cost of the system chosen, and the hydraulic performance of this system will be evaluated to determine valve operations.

I-6. Intake Designs

The intake designs considered for supplemental filling systems are largely dependent on the specific project requirements. For example, existing project features such as transmission lines or bridges may require the intake and supplemental culverts to be located so these features are not affected. The intake chosen for the proposed J. T. Meyers lock extension (described in section I-4) was a through-the-sill type design (Figure I-4) since this was one of the lower initial cost alternatives. The supplemental intake design for the proposed Greenup lock extension is shown in Figure I-6. This intake design consisted of 4 ports 10 ft wide by 18 ft high spaced 15 ft center to center with 14-ft submergence (from normal upper pool to intake roof). In general, the amount of debris that reaches the intake and the potential for strong vortex formation should be evaluated for the intake along with the hydraulic efficiency.

I-7. Outlet Designs

The extended chamber with supplemental emptying will require an additional outlet for lock emptying. Projects with landside auxiliary lock chambers may need to use landside outlets to minimize closure times for the main chamber during construction of the extended chamber. The outlet basin will need to be an effective energy dissipator to prevent excessive scour in the vicinity of the outlet and to avoid flow conditions that might adversely affect navigation in the lower approach. Outlet basin designs with baffle blocks will probably be necessary. An example of an outlet diffuser model tested for the J. T. Myers lock extension is shown in Figure I-7. The ports in the diffuser were angled downstream in an attempt to use the lock discharge to help minimize sediment deposition in the lower approach. The outlet basin for the J. T. Myers lock is shown in Figure I-8. The basin contained two rows of baffle blocks and was enclosed with an end sill type wall.

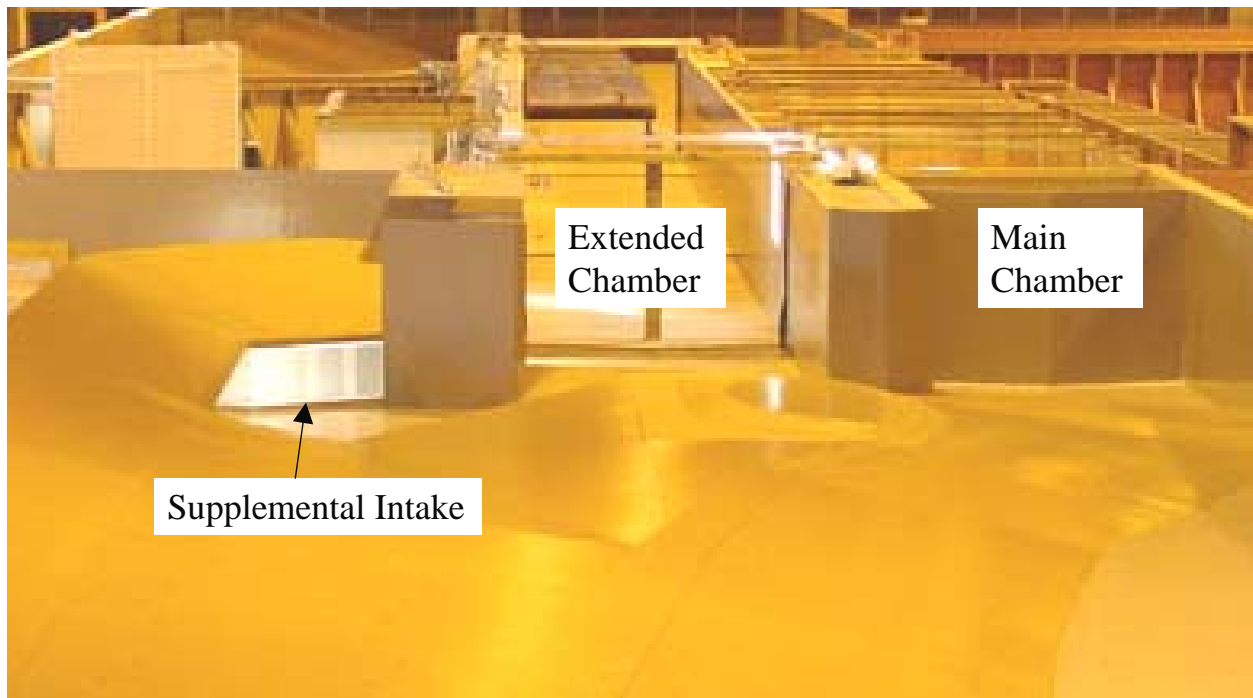


Figure I-6. Supplemental intake proposed for Greenup lock extension

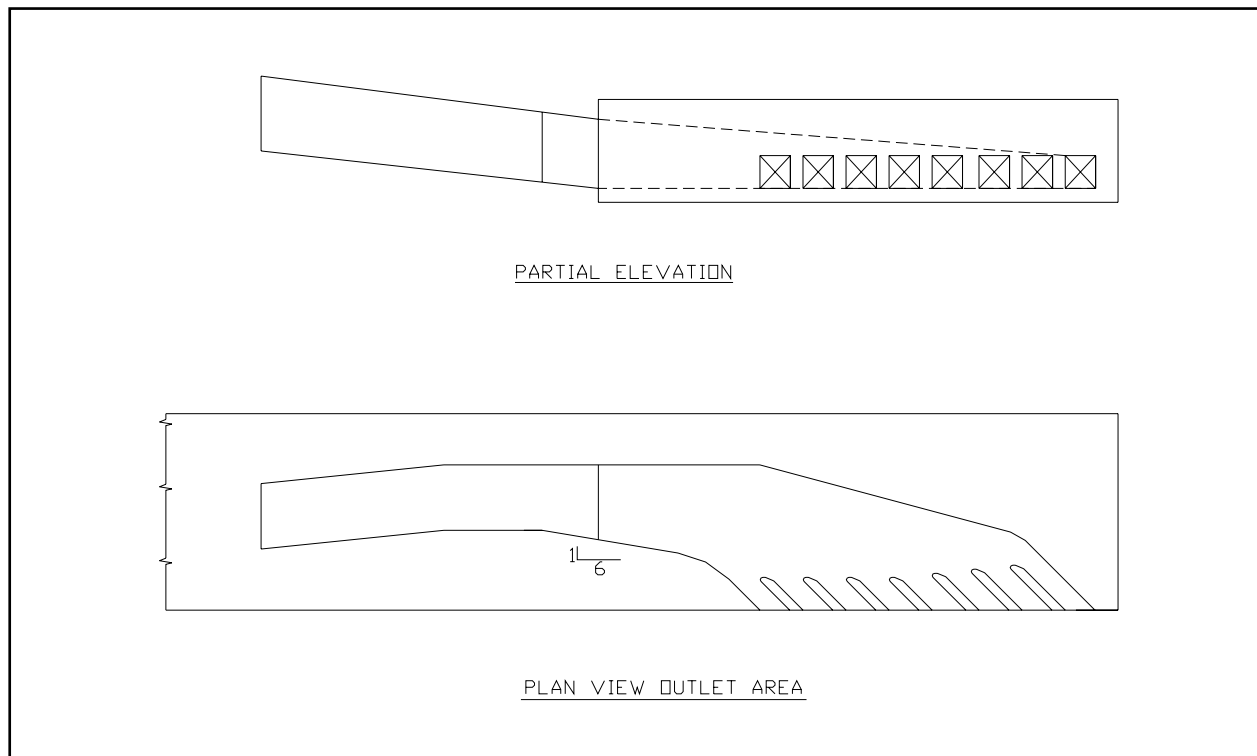


Figure I-7. Type 2 Outlet Design for J. T. Myers lock extension

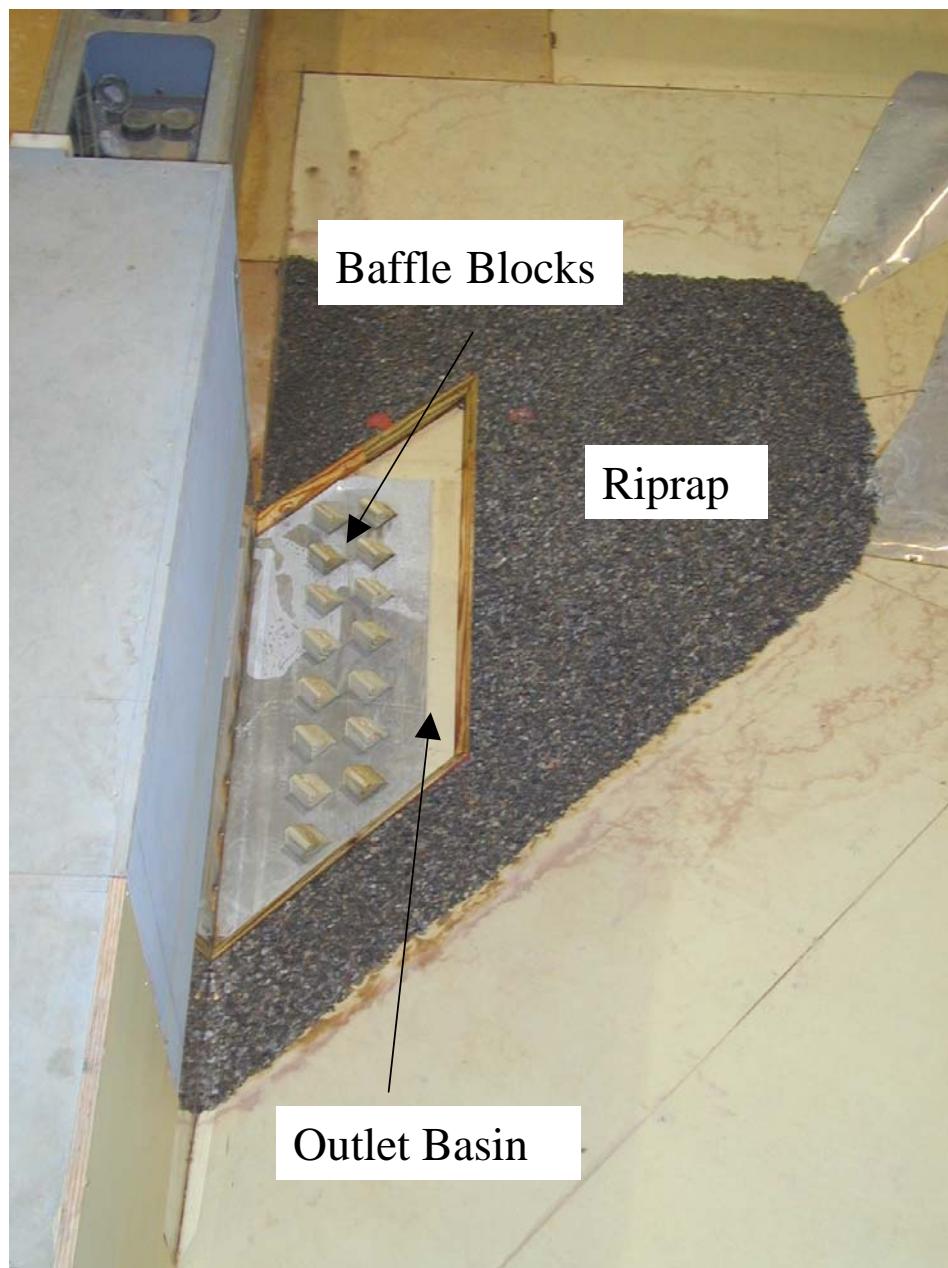


Figure I-8. Outlet basin proposed for J. T. Myers lock extension

I-8. Discussion

Lock extension studies have identified several issues that need to be evaluated during project design. As stated, a primary concern is to minimize navigation closure during construction of the lock extension appurtenances. A fast and safe system can be developed. The addition of a separate filling and emptying system for the lock extension will provide the most hydraulically efficient design. The best performance of the filling and emptying system addition will be to match the performance of the existing system. This will provide balanced flow during lock operations and avoid high hawser forces. The most hydraulically inefficient system is to use the existing filling and emptying system to fill the extended lock. This design is essentially an end filling system and is recommended only for low lifts. Extremely long valve

operations are required to prevent high hawser forces, and the chances for an accident caused from a fast valve operation are greater with this design. The lock extension design developed for the Upper Mississippi River locks is an intermediate type system where filling performance was sacrificed and emptying performance was improved to provide overall acceptable locking times.